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AP1

STOCHASTIC MODELLING OF DISPERSION FROM SINGLE ELEVATED SOURCES. E. Robertson and P.J. Barry, Atomic Energy of Canada Limited, Chalk River Nuclear Laboratories, Chalk River, Ontario, K0J 1J0

Short range (e.g. distances <50 km) atmospheric dispersion models have traditionally been used for two main purposes: a) to predict real time concentrations during accidental releases of noxious gases, and b) to predict long-term average concentrations for the purpose of controlling pollution levels from single sources during routine operations.

For several decades Gaussian Plume dispersion models together with published default dispersion parameters have been used for both purposes. However, during the last decade an increasing number of studies have shown that the reliability of such models and parameter values is poor when used to estimate pollutant concentrations for averaging periods of 1 hour or less.

These studies have been restricted to comparison of predicted to observed short-term concentrations in real time, but, by implication it is often implicitly assumed the model will be unreliable on the longer term as well. We have been conducting studies around an isolated stack that continuously released a short-lived radioactive noble gas, Argon-41, at a steady rate. This work has confirmed that on a one-to-one basis in real time the Gaussian plume model is a poor predictor for shorter averaging times with discrepancies by a factor of 10 or more occurring 80% of the time. However as the averaging time increases the reliability increases also and when the averaging time exceeded a month the predictions were acceptable. Annual predicted averages agreed with those observed within a factor of 2. It was also found that the cumulative frequency distributions of predicted hourly averaged concentrations agreed reasonably well with the observed distributions. Thus while the model gave relatively poor predictions of individual hourly average concentrations in real time it nevertheless yielded a reasonably correct ensemble of concentrations.

Thus it follows that, for prediction of long-term average concentrations, or the frequency distribution of concentrations, the model need not necessarily be driven by real time meteorological data, but rather by data synthesized from their frequency distributions, which are available in climatological summaries. The latter method is easier and thus less costly.

A stochastic dispersion model based on these ideas was therefore developed using the following methodology. The code performs Monte-Carlo simulations with variable input meteorological data fed to a standard Gaussian plume dispersion equation. The needed meteorological variables are wind speed and direction and a measure of the atmospheric stability. The climatological summary should provide the frequencies of wind directions on as fine an angular degree interval as possible; however, in the case of data derived from routine synoptic stations sectors of 22.5° intervals will have to be accepted. The cumulative frequencies are calculated going from 0° to 359° in whatever sector intervals are available. The resulting curve is fitted to a polynomial equation of the type



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$$D = a + bF + cF^2 + dF^3 \text{ -----}$$

where D is the wind direction, F the cumulative frequency derived from the data, and a, b, c -- etc. constants. Most computing systems support routines for the evaluation of the constants in a polynomial of any reasonable degree. The polynomial equation is written into the code. To select a wind direction for each "trial", a random number from 0 to 1 is generated, substituted for F into the above equation and D calculated. The complexity of the shape of the wind direction frequency curve determines the order of the polynomial that will give a reasonable approximation to the one observed. For the Chalk River site, where the wind is strongly channelled into two relatively narrow angular bands, a 9th order was required.

A similar procedure is followed to obtain values for wind speed and stability. Stability can be obtained using synoptic station data and the "STAR" program from which the occurrence frequencies of classes A to F can be obtained. Stability obtained this way is a discrete variable so that particular class is selected from the random number within ranges. For example suppose classes A, B and C occur with frequencies 2%, 10% and 15% respectively. Then Class A is selected whenever the random number lies between 0 and 0.02, class B when it lies between 0.02 and 0.12 and so on. Since wind speed and stability, as defined by the STAR program, are directly related, 6 wind speed distribution frequencies are used.

Once the class has been selected, values for the horizontal and vertical dispersion parameters can be calculated for the receptor distance from the equations provided by Briggs (1974) or Hosker (1974). These values together with a stack emission rate for the hours are used to solve the bivariate Gaussian plume equation and obtain a concentration for each receptor. The process is repeated as many times as necessary to obtain a smooth frequency of occurrences of concentrations or a stable estimate of the long term mean.

If the stack emission rate is independent of weather conditions it too may be selected randomly from a frequency distribution of values.

This model is to be applied to other sites to test its usefulness generally. As a first step it is to be applied to the smelter stack at Sudbury and the predictions derived from it compared with concentrations of SO₂ measured at several locations in the surrounding district.

If the model is found to be widely valid, it provides a relatively simple and straightforward way of calculating the stochastic characteristics for a climatology of air pollution events.

Predicting the long term mean is a useful product but knowing the frequencies of occurrences of different pollution levels about the mean enables regulators to also control the frequency of occurrence of toxic or nuisance levels. Alternatively if air pollution levels are regulated by applying meteorological control over sources, both regulators and regulated need to know the frequency and hence the potential costs of production cutbacks associated with any given strategy for pollution abatement.

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